Pre-Hercynian mantle lead transfer to basement rocks as indicated by lead isotopes of the Schwarzwald crystalline, SW-Germany

I: The lead isotope distribution and its correlation

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Abstract: Lead isotopes of K-feldspars from five granites of the SE-Schwarzwald and from metamorphites are positively correlated in 207/204- as well as 208/204- vs. 206/204-diagrams.

The linear alignments may be due to correlated last-stage lead isotope evolution (lead-lead isochron) and result in a secondary isochron model age of nearly 3 Ga for the Southern Schwarzwald basement. This calculation implies a long-lasting undisturbed lead isotope evolution in the Schwarzwald basement since the Archaean. This is not supported however by geochronological studies.

On the other hand the data together with U/Pb-analyses of whole rock samples from metamorphites are consistent with pre-Hercynian mantle lead addition to the basement. This presumably happened during early Paleozoic polymetamorphism. The interpretation of the lead isotope correlations as mantle-crust mixing lines needs a rather homogeneous pre-Hercynian mantle lead of the MORB-type, delivered to the crust probably in part by ascending volatile phases. Thus geodynamical models are supported which involve subduction of oceanic crust or mantle pluming during the early Paleozoic.

In Part I of this report, the trends in Schwarzwald lead isotopes are discussed as secondary isochrons and as mixing lines. Constraints are derived for a pre-Hercynian mantle-crust interaction and for lead redistribution by the Hercynian basement activation.

Introduction

Plate tectonic models have changed the understanding of the geodynamical and geochemical history of the European crust in the past decade. Forces and mechanisms that brought about the Hercynian orogenic belt of Central and Western Europe have been discussed continuously. The deciphering of the pre-Hercynian history of the European terrain, which was strongly overprinted by the Hercynian orogeny, is an even more difficult topic.

Different processes creating large continental mountain chains, such as subduction of oceanic crust along continental margins or collision of continental plates as well as accretion of continental fragments (Dewey and Horsfield 1970), have been thoroughly debated for the Hercynides (e.g. Nicolas 1972; Burrett 1972; Dewey and Burke 1973; Burrett and Griffiths 1977; Gebauer 1983). Collision and subduction of moving plates are potential phenomena leading to partial melting within the crust. They produce significant perturbations of the heat flow patterns and cause vertical transfer of volatiles, which are essential for crustal melting (Wyllie 1981). Subduction of oceanic crust beneath continental margins enhances magma and volatile transfer from mantle to crust accompanied by transport of incompatible elements (Anderson et al. 1978). In the course of continental plate convergence crustal melting may be due to mere intracrustal processes (Dewey and Burke 1973).

Isotope analyses of Sr, Nd and Pb help to decide whether the mantle participated in generating crustal melting by supplying volatiles or magmas. Similar to Sr and Nd, Pb isotopes may reveal different chemical fractionation of the radioactive parent-elements and their daughters in the various host reservoirs (e.g. evolution lines for mantle, upper and lower crust in the Doe and Zartman-model, 1979). Chemical incompatibility results in easy mobilization of lead, with magmas or gaseous phases acting as carriers (Vinogradov et al. 1971). Thus lead isotopes can be natural tracers monitoring mixing processes between mantle and crust. Consequently lead isotopes may yield boundary conditions for geodynamical and geochemical models.

A further field in which lead isotopes may serve as natural tracers is intrusional activity. Genetic relations between different rock types and element exchange between melts and intruded rocks can be studied. Such studies can check the consistency of geological models based on other isotopic and geochemical methods and offer additional information about the history of the basement.

An important study of the history of various Hercynian units by lead isotopes has been made by Vitrac et al. (1981). They observed a wide spread within the $^{207}\text{Pb}/^{204}\text{Pb}$ ratios of K-feldspars from various European crystalline rises. Though Hercynian mantle-crust interaction was not rejected, the data were interpreted by a model of mere crustal melting. This interpretation was favored because of the apparently unequivocal results of other isotopic and geochemical methods. Consequently, Vitrac et al. (1981) treated the conspicuous trend in their isotope data as a result of a long lasting evolution of the Central European...
crust (>3 Ga). The systematic spatial variations of the \( \mu \)-values (of the single-stage model) parallel pre-drift paleogeographical zones of the Paleozoic. Retardedly evolved lead observed within the ancient reservoirs is thought to indicate lower crustal magma sources.

A problematic aspect is the general discrepancy between the mentioned lead-lead isochron model age and age estimates of European crustal rocks by U/Pb work on zircons or by Rb/Sr analyses of whole rock samples. If an Archaean age of the European crust is taken as the basis for evolution models, then intense crustal reworking in the course of early continental evolution, accompanied by more or less complete resetting of the isotope clocks, has to be accepted. Rejuvenation is generally flanked by lead mobilization and an overprint of older lead isotope evolution trends. This is in contradiction to the apparently undisturbed lead evolution in the allegedly Archaean-aged crustal reservoirs.

For the discussion of the lead isotope patterns in the Hercynides it seems appropriate, therefore, to alternatively reflect on the possibility of isotopic imprints from reservoirs which are characterized by retardedly evolved lead. In order to avoid regional scattering within the lead isotope distribution, restriction to a limited area of the Hercynian belt was chosen, that is, to a single European crystalline unit. Such scattering could originate from accretion of unrelated continental fragments or from different reworking processes. The suite of analysed rocks was selected to include a series of Hercynian magmatites as well as older (possibly protolithic) country rocks. The data of Vitrac et al. (1981) for basement rocks from the Schwarzwald (SW-Germany) showed that this area is well-suited for such a study because of a conspicuously low radiogeneity of the K-feldspar lead. The Schwarzwald lead ratios are much closer to the composition of a less evolved source, which might have supplied contamination phases, than the lead composition of most other Hercynian crystalline units. (For the position of the Schwarzwald in Central Europe see Fig. 1). Lead isotope work using advanced analytical techniques and data evaluation have been carried out so far in the Schwarzwald by Todt (1976, K-feldspars from the Malsburg granite), by Lippolt et al. (1977, resp. 1983, galena veins of various localities) and by Vitrac et al. (1981, K-feldspars from granites and a durbachite). The galena lead isotopes indicated a complex evolution of the lead which could not be decoded conclusively without knowing the lead isotope compositions of the basement rocks. Metallogenetic implications of the basement rock data will be discussed elsewhere (Kober and Lippolt, in preparation).

**Geological setting**

The Schwarzwald basement belongs to the Moldanubian zone of the Hercynian belt. Its lithology, geochemistry and petrogenesis, as well as its geochronology have been modelled and reviewed elaborately during the past decades (e.g. Hoenes 1949; Mehnert 1953, 1957, 1962, 1963; Metz and Rein 1958; Brewer and Lippolt 1972, 1974; Emmermann 1973, 1975, 1977; Wimmenauer 1980; Weber and Behr 1983). The major constituents of the Schwarzwald basement are pre-Hercynian gneisses and anatexites in the central part of the mountain range, and three series of Hercynian granites in the south-western, south-eastern and northern part of the massif.

The Phanerozoic evolution started with a sequence of Precambrian/Cambrian greywackes and pelites that were intruded by melts in the early Paleozoic (ca. 520 Ma, Todt and Bünsch 1981) and affected by a first anatectic event. A regional metamorphism under generally medium grade conditions followed and transformed nearly all basement